(c) That, while division and section mean monthly temperatures are of some value for purposes of comparison in more or less level areas, they are of little use for that purpose in many rugged or mountainous regions. However, mean monthly temperatures in such rugged regions, if arranged and averaged by elevations, may serve many useful purposes, and tend to establish practically the effect of altitude on temperature, just as in the more level areas north to south division mean temperatures establish the variation due to latitude.

For instance, in the published climatological data for Colorado for April, 1927, there is no separation of the State into smaller divisions, but cooperative and other stations are arranged alphabetically in one list. The mean temperature for the entire State was computed from the several mean temperatures in this list by averaging them in one operation, and was found to be 44.2°.

If, however, we arrange stations and compute mean temperatures by altitudes from lowest to highest in several zones, say of 1,000 feet each, we have, beginning with the lowest zone, results as follows: 3,000 to 4,000 feet, 6 stations, mean temperature, 52.1°; 4,000 to 5,000 feet, 16 stations, mean temperature, 49.9°; 5,000 to 6,000 feet, 13 stations, mean temperature, 48.6°; 6,000 to 7,000 feet, 14 stations, mean temperature, 44.5°; 7,000 to 8,000 feet, 8 stations, mean temperature, 40.3°; 8,000 to 9,000 feet, 11 stations, mean temperature, 36.0°; 9,000 to 10,000 feet, 4 stations, mean temperature, 35.5°; 10,000 feet and higher, 4 stations, mean temperature, 33.2°.

This arrangement and averaging shows a more or less gradual drop in mean temperature from the lower to the higher zones. The average altitude computed from the elevations of the entire number of stations in the list is 6,416 feet, which falls in the 6,000 to 7,000 foot zone, the mean temperature of which, as obtained above, is 44.5°, only 0.3° higher than the mean temperature for the State (44.2°) as printed. Similar results have been secured from the data for other mountain States.

(d) That, while the demand for climatological data is constantly growing, and while inquiries are ever increasing in variety, response to which requires more and more time for special compilation, the limits of the publication have remained practically constant for more than a decade. The need for more detailed data on storm damage alone would frequently justify the extension of the printed matter by practically a page; and if we could insert in this publication data to answer inquiries regarding frequency of rainfalls and snowfalls of stated amounts, river stages and flood conditions, more complete information as to the effect of weather on crops, etc., still another page would be none too much.

Such questions as those briefly discussed in this paper, together with many others, some general, some pertinent to individual sections, are the problems of the Weather Bureau section director in serving the public interest. Their consideration, it is believed, should receive the attention of more than the individual official in his section; and in conclusion the writer begs leave to express the hope that at some time in the future it may be found practicable for the officials in charge of the climatological work of the bureau, both at the central office and in the field, to congregate from time to time to discuss in body these and similar questions, and to provide as far as practicable uniform and increasingly effectual methods of handling and publishing these valuable records of the cooperative climatological service.

FOREST-TREE DISEASES CAUSED BY METEOROLOGICAL CONDITIONS [1]

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When crops are poor, when epidemics of human disease are prevalent, or when forest fires rage over a wide territory, we are constantly reminded "It's the weather." The weather appears to be held responsible for many things, including rheumatism and the irregularities in the yearly growth of trees. Now come the forest pathologists to fill the cup to overflowing by stating quite calmly that meteorological conditions are responsible for a considerable number of important tree diseases. Fortunately, many of these diseases are of minor importance economically and do not greatly affect the life of a stand of timber. Others, however, cause considerable loss.

In a discussion of tree diseases, it is always helpful to group them under two main heads—(1) diseases caused by organic agencies such as fungi and mistletoes and (2) diseases caused by physiogenic agencies such as heat, frost, wind, and similar physical causes. The physiogenic diseases include all causes of disease which are produced by various atmospheric changes and disturbances, as follows: Sunscald, drought, wilting, frost cracks, frost heaving, frost bite, wind breakage, wind throw, wind deformation, red belt, sun scorch, too much or too little light, lightning injury, ice injury (sleet storms), snow breakage, snow smothering, snow heating, subsnow fungi, root suffocation (too much rain), gas injury, and dust injury.

FROST INJURY

Much has already been written on the cause and control of frost injury brought about by low temperature. In the literature are to be found several types of frost injury designated by various terms. Early and late frost injury, discoloration, wrinkling, slitting of leaves, and frost cracks are common injuries which result from the effects of direct freezing. Other types of injury such as "red belt" and a closely related one which may be aptly termed "sun scorch" or "sun burn" appear to be caused primarily by low temperatures but require the action of meteorological factors other than frost to bring about actual damage and the accompanying symptoms.

Frost injury in one form or another is fairly common in all regions where the temperatures fall below the freezing point of water. In the colder climates severe injury frequently occurs in seedling stock grown in forest nurseries and to transplanted stock. In the forested regions certain areas are known as frost pockets or frost centers in which frost injury is apparently more prevalent than in the adjacent areas. Topography and exposure are factors of importance which may account for such areas. Sun scorch and red-belt injury are confined to the coniferous forests and are most commonly, if not exclusively, reported occurring in the western coniferous belt.

Wilting takes place after severe frost injury and is followed by discoloration of the leaves and later on by a water-soaked appearance of the tissues. In some species the young bark turns a dark color. Tender tips and stems and young leaves are most susceptible and for this reason nursery stock often suffers severely.

Another common symptom of frost injury is the well-known frost crack or frost split which occurs in the trunks of some of our forest and ornamental trees. These radial

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cracks are usually found in the lower trunks, originating in the hollows of the root collar between the root spurs and extending several feet up the tree. They usually show considerable callus growth where healing of this type of wound is in progress. Repeated opening of the healed crack by subsequent frost and wind action forms on either side of the crack large callus growths which project some distance out from the normal circumference of the trunk and are often called "frost ribs." These cracks also extend into the heartwood for considerable distances and render the lower trunk useless for high-grade lumber or timber. Circular cracks or frost shakes are formed in some trees by low temperatures. Gummosis and resinosis are signs accompanying such injuries.

Since the younger and more delicate tissues are most susceptible to low temperatures, injury to leaders and to branch tips is of common occurrence in the frost belts. The resulting wilting and die-back are also symptoms of fungous diseases and care must be exercised in determining the original agency causing the prime injury. The tips of young trees in our western conifer forests frequently suffer from a peculiar type of frost or winter injury. The leader and one to several whorls of branches down from the top turn a bright wine red soon after bright sunlight followed a "cold snap." The whorls on the lower trunk which were buried in snow or otherwise protected from rapid thawing by sunlight remain green and the branches above snow level, or those exposed to the sun, become reddish in color. The tips and discolored branches die, causing deformed tops. In severe case the young growth is killed back until the tree has developed an abnormal bushy form.

Temperatures below the freezing point of water (0° Centigrade or 32° Fahrenheit) are indicated in the use of the term frost as an agency of tree diseases. Late frosts in the spring injure tender growing tissues while early frosts in the fall injure older plant tissues before they have become fully prepared for winter dormancy. Very susceptible young tissues may be injured at temperatures slightly above 32° F.

When the tissues of leaves and young stems are frosted water is either withdrawn into the intercellular spaces where ice crystals are formed, or the ice is formed partly or wholly within the cells. In either case water is extracted from the protoplasm and wilting takes place due to the reduced turgidity of the cells. If thawing is brought about slowly the water is reabsorbed by the cells without resulting damage and the plant again resumes its erect position. There are differences of opinion as to when and how frost action may prove fatal to the plant. Hartig (**1**), discussing the various angles of this problem, points out that the death of a plant by frost during winter bears a close resemblance to the effects of drought. Thus red-belt injury may be caused by a sudden thawing of the leaves in the crown accompanied by transpiration which removes more moisture from the leaves than can be supplied by the frozen trunk and roots. If the water deficiency in the frozen cells exceeds a certain limit and this amount can not be replaced by the adjacent tissues or supplied by the roots, the tissues die. Neger (**2**) has found that sunlight plays an important part in the revival of chlorophyll tissue which has been frozen. Conifers subjected to low temperatures revive fully if allowed to recover slowly in darkness, but develop discolored needles and cast them, in the case of spruce, if the frozen plants are allowed to thaw out in full sunlight. Photosynthetic activity during the time when little water is available and the cell sap is highly concentrated may bring about chemical changes which result in the death of the protoplasm. Hartig indicates that drought during open sunny winters when the roots are frozen accounts for considerable winter-killing. The conclusion is that death due to frost takes place at the time of thawing even in such cases, for it is upon the return of temperatures favorable to metabolism that the cells become active and die from lack of sufficient water.

RED BELT

In typical red belt there is a tendency for the older needles to be cast first and for the youngest needles to remain uninjured and attached to the tree. This is particularly noticeable in such species as Douglas fir (*Pseudotsuga taxifolia*) and Englemann spruce (*Picea engelmanii*), where all the needles but the youngest are cast and in addition the buds are often killed. In such cases the characteristic red crown is missing. Red belt is most pronounced on trees exposed to the east, south, and west, and on those bordering the stands or on isolated trees. There is a marked banding or grouping shown by the discolored trees which seems to follow the conformations of the topography, in some cases almost paralleling the contour lines (1, 3, 4, 5). These bands may be quite regular or irregular and may vary in width. Again, as in the 1924 winter injury to conifers in the Montana, Idaho, Washington, and British Columbia areas, the discoloration was fairly general with no distinct banding in evidence. Whenever the lower branches of red belt, winterkill, or sun scorch trees are buried in the snow they usually escape injury and bear a full set of healthy green needles. With regard to gross symptoms and primary agencies the two diseases known as red belt and winterkill may well be identical.

The symptoms of another type of winter disease known as sun scorch, sun burn, and sun scald are somewhat different from the above. Discoloration and death of the needles and tops, sometimes the entire tree, occurs on exposed trees, particularly the smaller isolated trees bordering a dense stand or growing along the edges of highways and railroad rights of way. The color is a bright wine red to reddish brown depending upon the species, and the discolored needles usually cling to the branch for a considerable period after injury has taken place. The lower crowns or individual branches, protected by snow banks, snow coverings or by neighboring trees, remain green. This presents a characteristic appearance—a dead and discolored upper crown with a green lower crown. The south, southeast, or southwest sides of affected trees show the greatest amount of discoloration and injury and trees growing in situations exposed to sunlight show the most severe damage. Many of the white firs (*Abies grandis*) and western red cedars (*Thuja plicata*) show a dwarfed or bunchy type of growth due to the killing of the leader and some of the upper branches. Examination of the stems of sun-scorched conifers in the region below and immediately above the edge of the dead tissue disclosed no signs of frost rings in the annual rings of the wood.

It is believed that, in all the types included under this group of physiogenic diseases, the direct cause of death is a shortage of water making itself felt in the needle or leaf tissues. In drought it may be the rapid lowering of the soil water table, a porous and shallow soil, injury to the root system, too rapid transpiration, prolonged hot, dry periods in the growing season, sudden exposure by thinning or removal of trees. In the case of winterkill and red belt, death is apparently caused by excessive transpiration of the needles during warm, sunny periods in the winter when the ground, roots, and trunk of the tree are frozen. Such sudden warm periods or "chinooks," as they are known in the northwest, usually follow a period of unusually low temperatures. During this warm period the heat and sunlight stimulate the leaves into activity and sufficient transpiration takes place to exhaust the available water. In this way the water column is broken since no water is obtainable from the frozen branch and trunk and the needles are unable to continue their normal activity and soon die.

Bright sunlight and rising temperatures, following a sudden period of low temperature, appear to be responsible for the injury known as sun scorch and the characteristic symptoms help to bear out this assumption. Neger (**2**) states that it is not so much the freezing action that causes the damage as it is the action of direct sunlight in rapid thawing and activating the photosynthetic cells of the needles. He conducted some interesting freezing experiments with spruce branches and found that the frozen branches which were revived in the direct sunlight developed discolored needles which were later shed, while those branches revived in a dark chamber recovered completely. Similar experiments were conducted by myself on branches of Douglas fir, lodgepole pine, yellow pine, western white pine, western hemlock, lowland white fir, concolor fir, Engelmann spruce, western red cedar, western larch, and jack pine. Two sets of branches of the above species were placed in an electric refrigerator at a minimum temperature of 18° F. for 16 hours. At the end of this period one set of branches was placed in the direct sunlight, their stems in water, while the other set, also supplied with water, was placed in a darkened cupboard. At the end of a 12-hour period the set exposed to sunlight showed a large number, nearly 50 per cent, of its needles discolored a light reddish brown and a casting of the injured needles had already begun on the Douglas fir, spruce, and larch branches. The set which thawed out in darkness under ordinary room temperatures remained green and healthy in appearance.

The bronzing of broadleaf foliage (**6**) may have its origin in a deficiency of water and it is common during dry seasons to find the leaves of mountain alder (*Alnus tenuifolia*), serviceberry (*Amelanchier alnifolia*), and occasionally of birches (*Betula spp.*) showing typical reddish brown discolorations in the leaf areas between the principal veins, known as the intercostal areas.

The direct cause of death in all such cases where frost and other agencies such as sunlight and rapidly rising temperatures seem to be coordinated, is the subject of much discourse. Is it the freezing or the formation of ice crystals that kills? Or is it the withdrawal of necessary water or a disturbance of the chemical balance within the frozen cell that results in injury or death? Abbe (**7**) ably summarizes the present concept regarding these questions as follows:

As the temperature of the plant cools the water exuding from the individual cells leaves a more condensed sap behind and the intercellular spaces are filled with purer water. Owing to capillary phenomena this water is not easily frozen until it has been cooled several degrees below the freezing point, and then its temperature suddenly rises to 32° F., as in the ordinary experimentation of the physical laboratory. The water within the cells is of course not yet frozen, being a more condensed sap, whose freezing point is usually lower than that of pure water. If now the temperature falls still lower, the ice cools, and eventually the sap within the cell is not more than sufficient to fill up the space formerly occupied by the water that exuded. If now the plant thaws out, the great mass of intercellular water escapes by transpiration. A little may go back into the cells, but this is a small percentage and oftentimes none. The plant wilts by the rapid loss of this water. Furthermore, a chemical change takes place in the cells by the excretion of pure water, and the cell sap that is left behind constitutes a new chemical compound. Such cells now change their character and their relation to the growth of the plant. Many of the excrescences and the diseases formerly supposed to be due to bacteria, or fungi, or parasites are found to be due to the chemical changes that have taken place within the cells in consequence of freezing. Thus Hartig shows that the frost *krebs*, or excrescence on trees, is a growth due to the effort of the plant to get rid of or cover up the dead cells produced by frost. When a frozen plant is young and tender and its leaves immature, the exudation through its tender cell walls may lie directly on the outside of the cuticle, but as the cuticle hardens in the mature plant, and the development of stomata becomes more complete, the greater part of the exuded water and its resulting ice is in the intercellular spaces. When the frozen plant is thawed out and evaporation is rapid, the loss of water either from the surface of the tender plant or through the stomata of the mature plant is much more rapid than under normal conditions and the plant wilts, but when there is no evaporation, the sap has time to return into the cells, and the wilting is not so severe. Therefore it is proper to say that the injury is not done by the more or less rapid thawing, but by the more or less rapid evaporation that accompanies the thawing. If similar plants are thawed out under warm and cold water, respectively, the rate of thawing has no influence on its health, as was shown by Sachs long ago. It is now seen that this is because in both these cases there is no special chance for evaporation, and the sap was able to go back into the cells; the contrary occurs when the plant thaws in the open air.

EFFECT OF HEAT

High temperatures cause wilting and heat lesions in seedlings and transplants, usually resulting in death; and, furthermore, may kill tender, frozen, or exposed young bark tissues causing a canker formation on the trunk, limb crotches, or larger limbs. The conditions, other than temperature, surrounding the plant at the time of injury are important with respect to the amount of damage caused. Heat cankers or bark scorch may be produced on the southwest sides of tree trunks when such trees are suddenly released from a dense shaded stand through logging operations, openings made for roads, highways, rights of way, fire lanes, or by the death of neighboring trees. These injuries, if severe, may girdle the tree, otherwise they form infection courts for the entrance of wood-inhabiting fungi. The color of the soil very markedly controls the damage caused by the high temperatures of direct sunlight. The darker soils, particularly the fire swept, charcoal covered soils, due to their high and rapid absorption of heat cause death to seedlings growing on them. Hartley (**3**), specifying measures to prevent stem lesions or whitespot injury of seedlings due to heat, says "Soil with loose texture or dark surface is presumed most likely to overheat at the surface."

A record, made by Forest Service investigators at the Wind River Valley Experiment Station, Washington, of seedling survival on two areas—one having a mineral soil, the other a black charcoal surface resulting from fire—showed a surface soil temperature of 143° F. and a loss of 100 per cent of the seedlings in three days' time, while on the yellow soil the temperature reached 125° F. with but a 16 per cent loss of seedlings. Neger (**2**, p. 25) states that spruce and pine seedlings can bear a maximum temperature of 54° C. without serious injury.

Both broadleaf and coniferous trees are subject to this type of disease. The more tolerant species, those possessing thin bark and those growing in moist sites, when exposed to sunlight, suffer severely. The most common examples of bark scorch and heat canker are to be found on orchard, shade and ornamental trees. Of the shade trees the maples, birches and beeches appear to be quite susceptible to this injury. Among the conifers, the white pines, certain spruces, Douglas fir and the true firs are sensitive to heat when the young tender bark becomes exposed to sunlight.

The primary cause of injury in this type of disease is the high temperatures affecting young, tender tissues.

Whether these high temperatures cause death of the tissues by killing or inactivating the protoplasm in the cells or by a form of dessication is not clearly indicated in the literature on the subject. It would seem that the lowering of the available water supply to a critical point through dessication would be a very important factor in reducing the resistance of the younger bark tissues to the injurious action of overheating. The overheating of leaves when a very high relative humidity is present, according to Neger (**2**, p. 24), results in a defoliation which is frequently more pronounced within the crown than on the outer parts.

Heald (**8**, p. 174) is of the opinion that winter injury is probably a more common cause of canker on both fruit and forest trees than the high temperatures due to bright sunlight. He states, however, that sun scald of some thin barked trees results from overheating during the intense sunshine and high temperatures of midsummer, coupled with a drying out of the tissues. A type of sun scald called winter sun scald is due to a combination of freezing temperatures followed by exposure of the frozen tissues to direct sunlight of sufficient intensity to cause injury.

SMOKE INJURY

The gases escaping into the air as the result of the incomplete combustion of coal, or the smelting of sulphurous and other ores, cause symptoms in trees which are recognized as signs of smoke injury. While the above two sources of harmful gases are the most important economically, there are a number of other sources which are accountable for similar, if less harmful, diseases.

Sulphur dioxide (SO_2) is perhaps the most common and the most injurious of the gases found in smoke. Hydrochloric acid, hydrofluoric acid, chlorine, as well as the finely divided solids found in smoke, have been recorded as harmful to forest trees. Previous work has shown, however, that smoke dust plays but a minor part in causing injury to forest trees.

While gases from industrial plants diffused in the air are the prime cause of the disease of conifers and hardwoods resulting in a wine red to reddish brown discloration of the foliage, the part played by the relative humidity, sunlight, and air currents is so important that I have included this disease in my discussion. Smoke injury takes place only under specific conditions; i. e., when the relative humidity is fairly high, when sunlight activates the foliage, and when air currents move the fumes to the susceptible trees rapidly enough to prevent too great diffusion of the harmful gases. In this manner meteorological conditions play most vital parts in the injury and death of forest trees by gases in the air. The effect produced on the host by smelter fumes, for example, so closely resembles the symptoms of several other diseases of conifers, including the various types of winter injury, that great difficulty is experienced in diagnosing the true cause of the damage when it occurs.

RAIN, HAIL, AND SNOW INJURY

These meteorological agencies cause injuries which are usually of the type of wounds in the tender bark tissues or of direct breakage of tips or branches. These injuries are important in that they frequently form the infection courts for parasitic and heartrot fungi. The sleet storms common in the Lake States and North Atlantic States often result in very serious damage to trees over large areas.

An estimate of the total weight of sleet borne by poles supporting telephone wires during a severe sleet storm in Wisconsin during the early part of March, 1922, gives us some idea of the strain which forest and shade trees are under when severe snow and sleet storms visit a region. Estimating that each linear foot of wire supported 4 pounds of ice, the 32-wire line with a span of 120 feet between poles had to carry a weight of 15,360 pounds in the face of a terrific gale. Even under such conditions the failures in the line were frequently traced to poles which had been weakened by decay at the ground line.

WINDFALL OR WINDTHROW

While not a true agency of disease excepting cases where prevailing winds acting upon exposed trees, such as in high elevations, cause a deformity of the branches and crown, yet wind action is an important factor in causing considerable loss in timber stands. Trees weakened by such factors as decay fungi, shallow root systems, moist, loose soils, sudden exposure by cuttings, site, etc., are very prone to be overturned by the force of strong winds. Within recent years large areas of timberland have suffered this type of injury. The breakage of tree trunks and of branches often results from high-velocity winds.

Such "blowdowns," as they are termed along the Pacific coast, have occurred in recent years along the Olympic Peninsula, where large areas of mature timber have been swept to the ground. The tangled condition resulting from windfall and the isolated areas in which they frequently are found, makes it impossible to salvage the timber before deterioration of the sapwood takes place. Within two to three years much of the sapwood and some of the heartwood is deteriorated through sap stain and decay fungi.

ELECTRICAL OR LIGHTNING INJURY

Lightning, aside from the setting of forest fires, causes considerable injury to trees in a forest. The breakage of tree parts and the splitting and shattering of tree trunks are the more conspicuous signs of lightning injury. However, the injury due to minor lightning bolts, to spray lightning, for example, is often hidden beneath the bark and reveals itself only as lightning scars in the annual rings. These false rings along with those produced by frost and other pathological agencies are a common source of error in counting the annual rings of a tree in an attempt to determine accurately its age or an historical date in the life history of the tree.

Lightning rings are common in certain species of trees and in trees growing in lightning zones. Sitka spruce, prized for its strength properties and light weight in airplane construction, frequently shows these false rings caused by lightning. As defects in airplane wood or woods requiring rigid strength specifications, these hidden injuries are of considerable economic importance, since failure under stress is most likely to take place along a false ring.

Before closing it will be of interest to dwell for a moment on the topic of ring or annual growth measurements in trees and their significance. Insufficient precipitation and the consequent lowering of the available water level in the soil is responsible for more injury to forest trees than most of us appreciate. Drought injury not only causes reduced growth and reduced vigor in trees, but it also predisposes the tree to attack by organisms which hasten its death. The reduction in annual growth alone represents an appreciable loss and this brings before us the interesting relationship between annual growth measurements and periodic changes in annual precipitation. A tree reflects in its annual rings any reduction in growth activity caused by a large number of factors of which the annual supply of moisture is but one. Anything, from insect attacks, fire injuries, crowding of individual trees, sun scorch, to a variety of fungous and parasitic plant pests, may leave their record in decreased width of annual rings. The great problem is to eliminate all factors but one in each study. It is also a well-known fact that the width of the same annual rings varies considerably in different parts of the trunk. This makes it necessary to depend upon borings in various parts of the trunk from base to top. The frequent occurrence of false rings, double rings, and the absence of certain rings all contribute to the difficulty experienced in reading accurately the past history of the tree from the face of the stump.

I point out these facts to emphasize the large number of variables involved and the need of accumulating a great number of data on such growth correlation studies before conclusions may be hazarded.

An interesting piece of work of this nature has been done in our Idaho forests by Marshall (**9**), who found by measuring the ring growth of western white pine trees that the climate of northern Idaho has exhibited distinct wet and dry periods, varying in length from 20 to 40 or more years. The wet periods he found to be from 1706–1745, 1785–1825, and from 1846–1885. The dry periods were sandwiched in between the wet periods and were from 1746–1785, 1826–1845, and from 1886–1925.

These brief accounts represent but a few of the most important tree diseases which may be placed at the door of the weather man. There are a number of minor disturbances of the functions and damages to parts of trees which have not been touched upon. Enough has been presented to indicate the important rôle that meteorological conditions play in causing economic losses in our timber stands. Windthrow, winter injury, and drought injury are alone responsible for a very formidable loss over a period of years.

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THE RAINFALL OF SALVADOR [1]

By ADELBERT K. BOTTS

[Clark University, Worcester, Mass., December, 1930]

The rainfall of Salvador is an excellent example of west coast trade wind precipitation on the northern margin of the equatorial rainfall belt. The average annual rainfall of the country is 75 inches, an amount which is usually considered very bountiful. However, the distribution, both seasonal and areal, tends to restrict the benefits to certain rather definite periods and places.

Salvador is located on the western side of the Central American Cordilleras between the latitudes 13° and 14° 30′ N. The central part of the country is occupied by a belt of volcanoes, the highest one less than 8,000 feet high, and most of the peaks less than 5,000 feet high. The ridge is high enough, however, to affect the distribution of the rainfall. (Fig. 1.) The rainfall is considerably heavier on the side exposed to the ocean than it is in regions farther from and protected from the ocean. It is generally true that the amount of rainfall varies directly with the altitude of the land. (Fig. 2.)

A comparison of the average annual rainfall conditions of four representative stations shows further consistent modification with elevation. (Fig. 3.) Cutuco has two periods of maximum rainfall, one occurring in June and the other in September. They are separated by a period of distinctly diminished rainfall in July. For each of the remaining three stations the sharp distinction between wet and dry periods during the summer months is progressively modified with increasing altitude. San Salvador, 2,076 feet above the sea, has one continuous wet season lasting from April to November. It seems reasonable to assume that elevation is the controlling factor in this situation, since a study of data for other stations verifies the assumption and since the differences in latitude between the various stations is so slight as to be negligible.

Another modification resulting from increased elevation is decreased variability in amount of rainfall received from year to year. This fact is made evident by a comparison of the differences in the absolute extremes of rainfall by months for the various stations. On the Cutuco chart the vertical lines between extremes are very long. The length of corresponding lines for stations at higher elevations is generally shorter. A short line for any month indicates a slight variability in the rainfall for that month, which amounts in fact to greater uniformity from year to year. San Salvador, the station at the highest elevation, has, generally, the least monthly variability in rainfall from year to year. That seems to indicate that rainfall over a period of years is somewhat more uniform at high than at low elevations.

Rather important in the seasonal distribution of rainfall is the fact that a low total for a year does not imply a consistently dry year, nor a high total a consistently wet year. For Cutuco, the year with the least total rainfall (dotted line) shows rainfall much above the average for the first part of the rainy period, with June for that year the wettest June on record. In that case the second part of the rainy period was the one which cut down the total while the first half of the summer was wetter than usual.

[1] This study was presented to the Association of American Geographers, in their twenty-seventh annual meeting held at Clark University, Worcester, Mass., Dec. 29 to 31, 1930. Acknowledgment for the data upon which this study is based must be made to Mr. Fred Lavis, president of International Railways of Central America, who sent the material to Clark University. Use was made also of Mr. W. W. Reed's article, Climatological Data for Central America, in the MONTHLY WEATHER REVIEW, vol. 51, p. 133.